

REMOTE SENSED RESOURCES SURVEY OF DOON VALLEY

A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

by
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to the

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KANPUR
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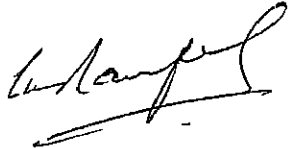
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CERTIFICATE

Certified that this work "REMOTE SENSED RESOURCES SURVEY OF DOON VALLEY" has been carried out by Sri Rakesh Kumar under my supervision and the same has not been submitted elsewhere for a degree.

May, 1986


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ABSTRACTS

Assuming that the objectives for making an inventory of natural resources in a given area can be met by interpretation of Landsat multispectral scanning (M.S.S.) imagery and subsequent field and laboratory investigations, the first step at the preparation stage clearly is the acquisition of the most relevant satellite data. However, an understanding of the basic image selection procedure alone is not sufficient to achieve optimum results. Therefore a practical methodology such as describe in this thesis is considered to be vital.

Visual interpretation of Landsat M.S.S. imagery differs from small scale aerial photo interpretation inspatial, spectral and temporal resolution. The latter two aspects allow for the design of a methodology in which optimum use can be made of so-called static and dynamic image interpretation elements. Static elements such as drainage pattern, alignments and landform are less seasonal dependent but of course influenced by image quality and cloud cover. Dynamic elements such as drainage condition, as reflected by moisture status, vegetation and agricultural land use are season dependent. Each of the above elements which to be integrated into the final physiographic analysis is interpreted in the best spectral band and season there of. The area of study is taken of the Dehradun region, (U.P.), Northern India.

CHAPTER - I

INTRODUCTION & OBJECTIVE

1.1 INTRODUCTION

For effective and efficient small scale resources surveys of large areas in developing countries the use of LANDSAT MULTISPECTRAL SCANNING (MSS) imagery can be a tremendous aid prior to or in conjunction with modern aerial photo interpretation technique.

A whole range of landsat products and interpretation facilities are available now-a-days both for visual interpretation as well as computer assisted analysis. However, in developing countries there is an need for an intermediate technological approach to Landsat image interpretation. Such an approach would involve visual interpretation of black & white colour composite produced as prints or transparencies in working scales varying from 1:150,000 to 1:100,000,00 using simple instruments.

In areas where no aerial photography is available this may serve as a tool at the exploratory or inventory level for further planning of aerial and coverage of the most promising areas for agricultural development. In other cases it serves to complement inventories or reconnaissance surveys where small scale aerial photography is applied as well.

Compared with small scale aerial photography, Landsat imagery has definite advantages in the domain of the multispectral and multitemporal scanning of the earth's surface. Although at present Landsat has a low spatial resolution and its imagery still offers only limited possibilities for stereoscopic vision, it is expected that these drawbacks will be improved considerably in future satellite systems.

The imagery used for the interpretation of natural resources covers the Doon Valley and surrounding hills with boundaries as follows.

North	--	Yamuna River and Algar River
East	--	Ganga River
South	--	Boundary of Sivalik with plains.
West	--	Yamuna River

The area is situated between 77° 30' and 78° 15' longitude and 30° and 30° 30' latitude covering an area of approximately 3000 square kilometers. It comprises 3 broad geologic units.

1. The Siwalik range in the South.
2. The Doon Valley forming a trough in the centre.
3. The Himalayan foot hill range of Mussorie in North.

The Siwalik hills deriving from the Northern Himalayas contain certain tertiary rocks. The Doon Valley consists of young sedimentary material over tertiary rocks and is divided by a

fault line from the rocks on the lower Himalayas. These are old tertiary to Pre cambrian in origin.

The Doon Valley is 70 km long and 20 km wide and the land is mainly under cultivation. The forest areas are situated on the slopes of Siwalik hills and the Himalayas. The vegetation ranges from tropical in plains to temperate in the Himalayas (Fig. 1.1).

The LANDSAT - 2 images used in this study were the four MSS bands 4, 5, 6, 7 exposed on 12th February 1973, scale 1:1 M and Landsat - 4 image at scale 1:250,000. All four bands were of good quality without interference from clouds. The MSS bands used were No. 4 to 7 in which wavelength are:-

Band 4 (green)	0.5 to 0.6 micrometers
Band 5 (lower red)	0.6 to 0.7 micrometers
Band 6 (upper red- lower in-frared)	0.7 to 0.8 micrometers
Band 7 (infrared)	0.8 to 1.1 micrometers

1.2 OBJECTIVES

The objectives of the work is to carry out resources survey of Dohra Dun by the use of the following:-

- i) Preparation of a map of drainage pattern of the area which covers

- (a) Siwalik Range in South
- (b) The Doon Valley
- (c) The Himalayan foot hill range of Mussoorie in North

- (ii) **Tracing** the alignment or lineament of above area
- (iii) To show the Landform of above area
- (iv) To prepare a map for drainage condition and snow cover of above area
- (v) To prepare the map for vegetation land use, built up area.
- (vi) To interpretate all the maps alongwith Landsat imagery by visual interpetation method and get a various knowledge about the area as best as it can be done.

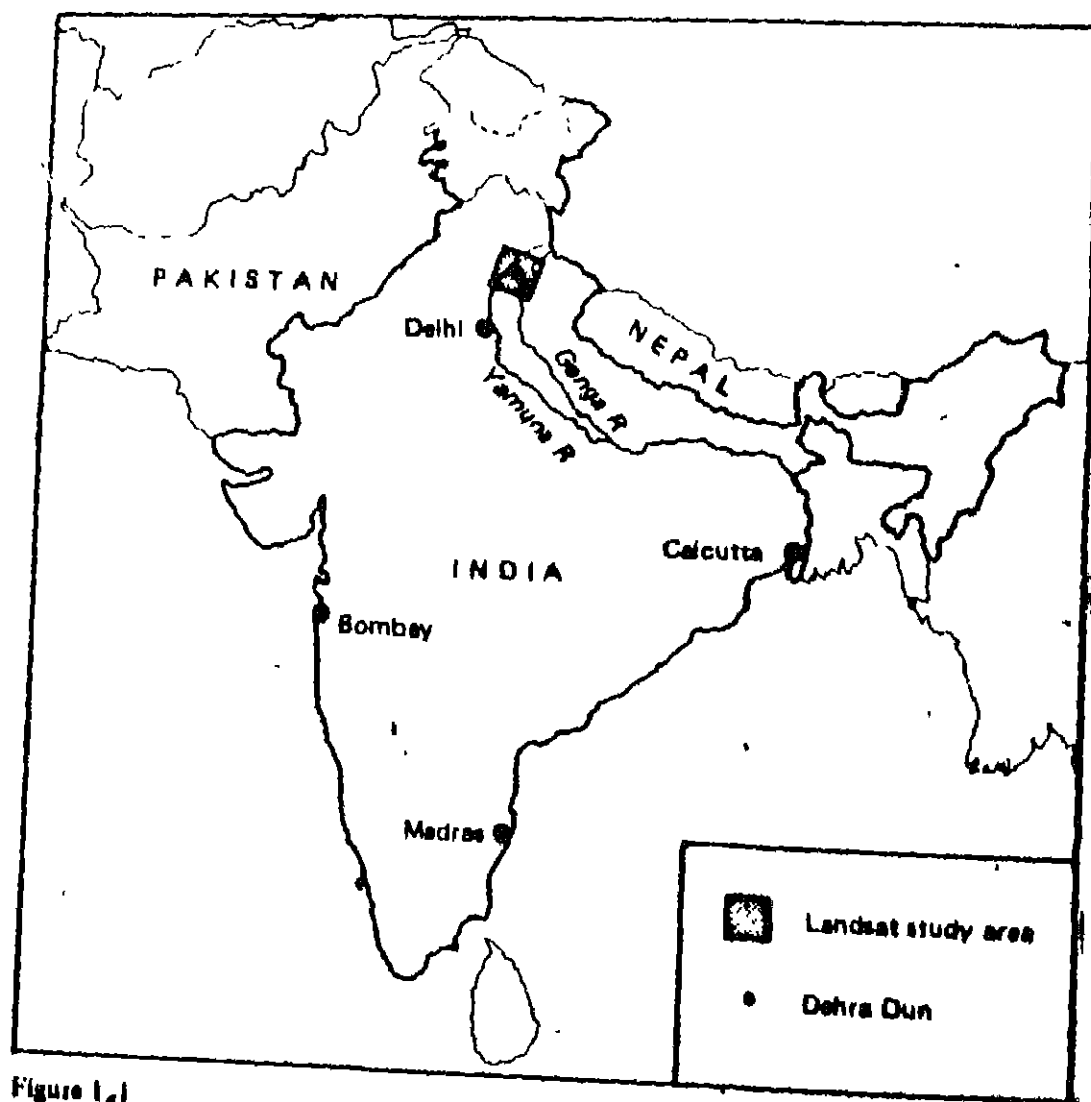


Figure 1a)
Location map showing study area in Northern India

CHAPTER - II

SELECTION OF IMAGERY

The most promising satellite MSS data for Multispectral study of natural resources can be obtained if careful consideration is given to the following factors (Table - 2.1).

- (i) image quality
- (ii) cloud cover
- (iii) snow cover
- (iv) soil moisture regime
- (v) vegetation crops & side lap (6)

The above factors are important for both visual interpretation as well as digital analysis of Landsat MSS data.

Crop calendars and precipitation/temperature diagrams to diagnose so-called dry moist and wet season are valuable tools in the procedure on selection of Landsat imagery (6, 8). The proposed area of study (Dehradun region, North India), comprising a part of the Himalayan mountains, Siwalik foot hills and the Indo Gangetic plains is to be found in World bank Landsat Catalogue under path No. 157 row 39 (12). (Fig. 2.1).

In an earlier investigation systematic selection procedure (8) Six Landsat scenes of four different seasons were ordered. Preliminary inspection of the selected seasons was carried out with respect to their information content for dominantly static image

interpretation elements such as drainage pattern, alignments and land forms as well as dominantly dynamic elements such as drainage condition, as reflected by moisture status and vegetation land use. Table 2.2 summarises the results of preliminary inspection of six Landsat scenes ordered.

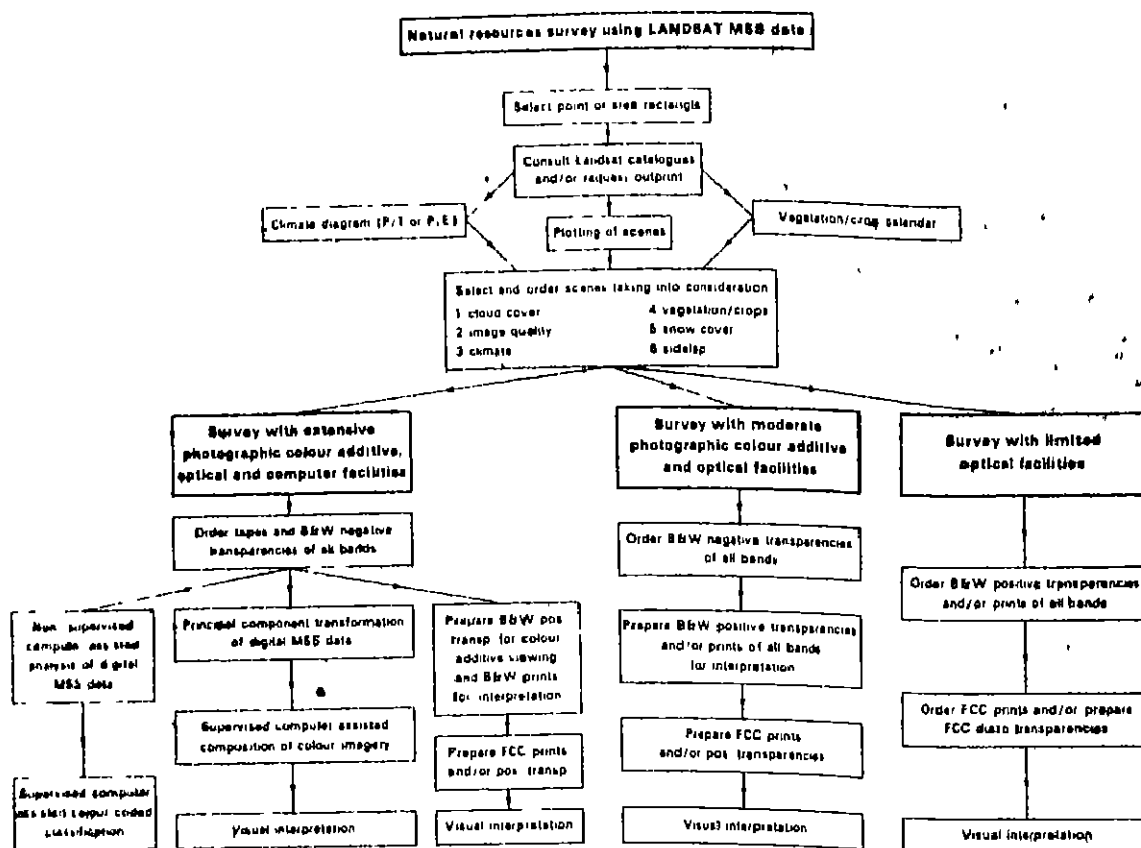


Table 2.1

Selection of Landsat MSS data for interpretation purposes of natural resources surveys using limited, moderate or extensive instrument facilities

TABLE 2.2

Preliminary inspection of selected Landsat scenes for the survey of a part of Northern India.

Season	Month	Interpretability
Dry/Cool	Nov. 73	Good for interpretation of alignments, land form, relief, drainage condition are land use.
Moist/Cool	Feb. 73	Good for interpretation of land use with crops such as wheat and Sugarcane
Dry/Hot	May 73	Good for interpretation of natural vegetation of Sun exposed slopes of foot hills.
Wet/Hot	Jan 73	Good interpretation of drainage pattern, Wet lands (Tarai), irrigated and non irrigated agriculture.
	Jul.73	

421 5



Fig 2-1 Landsat image of the Dehra Dūn region, Northern India

CHAPTER - III

MATERIAL & INSTRUMENTS

After definition of the objectives including the details of the survey, it is possible to decide on the most suitable materials and equipments to be used.

The application of Landsat is of primary importance in the range of 1:100,000 to approximately 1:1 M scale natural resources survey preferably in conjunction with small scale aerial photographs.

As in the case in aerial photo interpretation a more detailed approach in Landsat imagery interpretation requires more naturalists and often more expensive equipment. Extensive facilities for computer assisted analysis may result in speedy classification of spectrally separable classes for vegetation and land use mapping.

For most of the studies limited study optical facilities such as those available in basic remote sensing unit including those in developing countries have been used in the course of this study. During the interpretation, use was made of light table, a magnifier times two and a minor stereoscope.

The material used for the interpretation of the Dehradun region consisted of good quality 23 cm black & white paper prints of Landsat MSS bands 4, 5, 6 & 7 and ~~diazochrome~~ false colour composites (F.C.C.'s) of four season at a scale of 1:1 M. The

F.C.C.'s were obtained from positive transparencies of MSS bands 4, 5, 7 with a density and contrast in a range most suitable for diazo process. Band 7 MSS imagery on scale 1:250,000 was also available at the later stage of investigation.

MSS 4, 5, 6 & 7 correspond to four Landsat wavelength bands 0.5 - 0.6, 0.6 - 0.7, 0.7 - 0.8, and 0.8 - 1.1 m respectively.

Use was also made of existing geological map of the area on the scale 1:50,000 of sheet No. 53 J/3.

Also using monoscopic interpretation procedures such as these employed in this study has possible to apply various enhancement technique through binocular studies of manoband, multiband, monotenporal and multitemporal Landsat MSS imagery (6).

CHAPTER - IV

LITERATURE SURVEY

4.1. REVIEW

In the past quarter century three major approaches have been made in developing techniques of photo-interpretation for soil survey, viz 'pattern analysis' by Frost et al (1960), 'element analysis' by Buringh (1960), 'physiographic analysis' by Butler (1959) Vink (1963) and Goosen (1967). A 'physiogramic method' such as advocated at I.T.C. by Bennema and Galen Surce (1969) is a modifier of the 'physiographic approach'.

At the International Institute for Aerial Survey and Earth Science (ITC), The Netherlands, the foundation for the landscape aeriaded approach were laid by Buringh (1960) Vink (1963).

Vink further developed the use of physiography in photo interpretation. He distinguished the following phases, detection, recognition, and identification, systematic analysis, physiographic classification with individual elements and physiographic systems, soil deduction.

Development of other remote sensing technique (analoguo/digital) in space such as multispectral photography (Gemeni, Skylab) and multispectral scanning (Landsat) from satellite platoforms has resulted in a stream of data with quite different image characteristics (spatial, spectral, temporal). Although

the detail and stereoscopic of the present Landsat MSS system is inferior to that of small scale aerial photography, the former offers specific advantages in the domain of its monitoring capability and of the infrared part of the spectrum due to the wider wavelength range compared with photographic sensors. New expensive digital interpretation techniques are being developed solely based upon spectral reflection of water, soil, rock, and vegetation types. The recorded colour tones and vegetation grouping from only two out of a dozen main individual elements used in modern aerial photo interpretation. They may be of limited use of soil surveyors, particularly when there is a poor correlation between vegetation/land use and soils.

Three years after the successful launching of the first Landsat, the manual of Remote Sensing was published (1975) containing the following passage.

"There is a little information available at present concerning the visual interpretation techniques for orbital and hyperlatitude photography and imagery. Specifically which recognition elements are most useful and which may be of limited value. How do interpretative practices for conventional aerial photography differ from those taken from space"

In the meantime some interesting papers have been published including that of Van Garderen and Vass⁽¹⁹⁷⁴⁾ (1976) on the use of Landsat data for rural surveys, focussing mainly on procedures

including materials and instruments. It lacks detailed information on the methodology of image interpretation. Some authors (Daels & Antrop 1977) stress the importance of stereo vision and physiography in addition to the well known criteria of image interpretation such as tonality or colour, texture and pattern for the extraction of soil information from remote sensing documents. But they apply this only to aerial photography and limit themselves to the latter group in the case of Landsat imagery.

The criteria of the Manual of Remote Sensing⁽⁴⁾ Chapter 15, Fundamental of image interpretation described as size, shape, shadow, tone or colour texture, pattern and aided by site, association and resolution may be applied for land use and crop survey procedures, but are inadequate as primary elements for a physiographic analysis. An excellent and practical guide in Landsat image interpretation is the Work of Sabin (1968) 'Remote Sensing, principle and interpretation, though it deals mainly with Geosciences, particularly geology.

4.1.1 IMAGE INTERPRETATION IN SOIL SURVEY

In the image interpretation each image conveys ideas or impression. These ideas or impression are interpretations such interpretation may or may not be accurate, and may be either conscious or unconscious, partial or complete. Nevertheless, interpretation is an essential process through which information is obtained from images. Once the interpreter has gained facility

with the techniques of observation, he can then address the difficult task of developing and using logic to draw accurate conclusion from the images he observes.

Image interpretation is defined as an act of examining images for the purpose of identifying objects and judging their significance. Interpreters study remotely sensed data and attempt through logical processes to detect, identify, measure and evaluate the significance of environmental and cultural objects, patterns and spatial relationship. Imagery of large areas permits the observer to perceive the relation of objects and surroundings which to an observer on the ground might not be apparent. The image interpreter can examine objects patterns and relationship in detail and can compare those data with maps and other reference material.

Stereoscopic viewing enables the shape and height of objects to be determined. Perception of forms makes it easier for the interpreter to identify objects and permits measurements of height and slopes.

An image interpreter is a limited sensor. The interpreter perceives reflected energy in a narrow band of electromagnetic spectrum. Sensor system and photographic emulsion currently in use however enable the interpreter to view picture like images of energy pattern beyond the limit of his vision. These energy relationship add significant information as the interpreter

INSTRUMENT FACILITIES (AND APPROXIMATE COST) REQUIRED FOR LANDSAT MSS

INTERPRETATION IN RELATION TO THE CATEGORY, PURPOSE AND PUBLICATION

SCALE OF THE SOIL SURVEY

General Category of the map*	Purpose of the survey*	Publication Scale	Landsat materials**	Interpretation instruments	Facility and approx. cost
Exploratory/schematic	comparison of areas, international level	smaller than 1:1 M	B & W and FCC pos. transp. and/or prints	light table; magnifier; mirror stereo-scope; slide projector; diazo printer	limited facility; budget**** US \$ 2500.
Generalised/schematic	general inventories national level	1:250,000/ 1:1 M	B & W neg.*** transp.	in addition to instruments above: colour additive viewer; zoom transfer scope	moderate facility budget**** US\$ 25000.
Reconnaissance/generalised	very large projects, regional level	1:100,000/ 1:250,000	B & W neg.*** trans. and computer comparable tapes (CCT's) analysis	in addition to instruments above: facilities for computer assisted	extensive facility; budget**** US\$ 250,000.

*) According Soil Survey Manual (USDA, 1962)

**) Primary materials to be ordered at distribution centres of Landsat MSS data, e.g. EROS Data Center, Sioux Falls, USA.

***) Presence of a photographic laboratory is assumed to prepare derived Landsat MSS products

****) Budget 1979.

attempts to judge the significance of objects, phenomenon and relationship in the environment.

Image interpretation differs from direct observation in aerial scope, perspective and temporal relationship. It is similar to direct observation in one important respect, the amount and reliability of the information obtained depends upon training and aptitude of observer and on the nature of scene observed. Basically, image interpretation is to photogrammetry as statistic is to mathematics.

4.2 MULTITEMPORAL PHYSIOGRAPHIC LANDSAT ANALYSIS

This presents a low cost methodology for the visual interpretation of carefully selected multitemporal landsat MSS data for inventories of natural resources by integrating static and dynamic image interpretation elements. Low cost refer to low input in terms of capital. However a high input is required in terms of expertise regarding image interpretation techniques i.e. a specialist well trained in aerial photo interpretation and Landsat analysis.

The interpretation procedure is:-

(i) Visual, (ii) Multitemporal using (iii) Existing information (topography, geology etc) and is carried out with (iv) Limited photographic and Optical interpretation facilities which make (v) This suitable in most developing countries.

CHAPTER V

IMAGE INTERPRETATION ELEMENTS

Image interpretation is defined as the act of examining images for the purpose of identifying objects and judging their significance. Interpreters study remotely sensed data and attempt through logical processes to detect, identify measure and evaluate the significance of environmental and cultural objects, pattern and spatial relationship.

Imagery of large area permits the observer to perceive the relations of objects and their surroundings which to an observer on the ground might not be apparent. The image interpreter can examine objects pattern, and relationship in detail and can compare these data with maps and other reference material.

The guiding principle of the proposed multitemporal physiographic Landsat MSS analysis is the use of best band of the most relevant season for a particular image interpretation element, these element then integrated into the final physiographic analysis ready for field investigation and subsequent re-interpretation. Such an analysis may be regarded as optimum interpreters map for soil survey purpose.

5.1 DRAINAGE PATTERN

Drainage patterns are an important aid in image interpretation because they can be used as criteria for identification of hydrological, structural, lithological and topographical phenomena. In geomorphic aerial photo-interpretation numerous examples are given of the most common drainage patterns in descriptive terms such as 'dendritic' etc. Drainage patterns can be further subdivided into erosional, depositional and special patterns. In addition to the patterns described above, combinations may occur in various degrees of integration, density and uniformity, which is indicative of different area characteristics. Daels & Antrop (1977) distinguish some fifteen principal drainage patterns as an indicator of lithology and landform. In geological interpretation some ten main drainage patterns are described (9).

In the Landsat image interpretation procedure proposed in this paper a distinct difference is made between drainage pattern and drainage condition, the former one being independent of seasonal changes. Two of the most prominent drainage patterns. Figure 5.11 shows the drainage pattern of the Doon Valley (Siwalik Range, Doon Valley, Himalayan foothills). For the interpretation of drainage pattern Landsat imagery of band No.6 (Wavelength $-0.7 - 0.8 \mu m$) and band No. 7 (Wavelength $-0.8 - 1.1 \mu m$) are used. If we plot percentage of reflectance of incident energy versus the wave length we get curves as shown in Figure 5.12. It can be seen that the behaviour of different objects is characteristic of the

of the object for its reflectance for different wavelength is concerned, for example as in Figure 5.12 Water, Vegetation and Soil show entirely different reflectance to incident wavelength especially towards the longer wavelength. In case of water it absorb all the incident energy as far band No. 6 and band No. 7 is concerned (Wavelength $0.7 - 1.1 \mu\text{m}$). So it appears black in Landsat imagery and can be easily discriminated from other objects.

There are two major river in the study area. One is River Ganga and other one is River Yamuna. On the top of Himalayan region snow is found which is the main source of discharge for the rivers. On the satellite imagery the demarcation of snow line can easily be done but the determination of depth is little difficult, because its thickness varies according to season. Springs and their several tributaries are found in the Himalayan and the foothill of Siwalik. They finally contribute discharge for the above rivers. Most of the springs are drying up or going seasonal because the loss of vegetal cover has reduced the capacity of sloping grounds to absorb and infiltrate rain waters and feed the springs.

The river Ganga originates from Gangotri (top of Himalayan) comes at plain in Hardwar. There is a major canal which came out from Ganga at Hardwar goes beside Roorkee, Muzaffarnagar, Meerut and finally meets the river Yamuna. The Canal is the main source of irrigation of plain area. The river Yamuna originates from

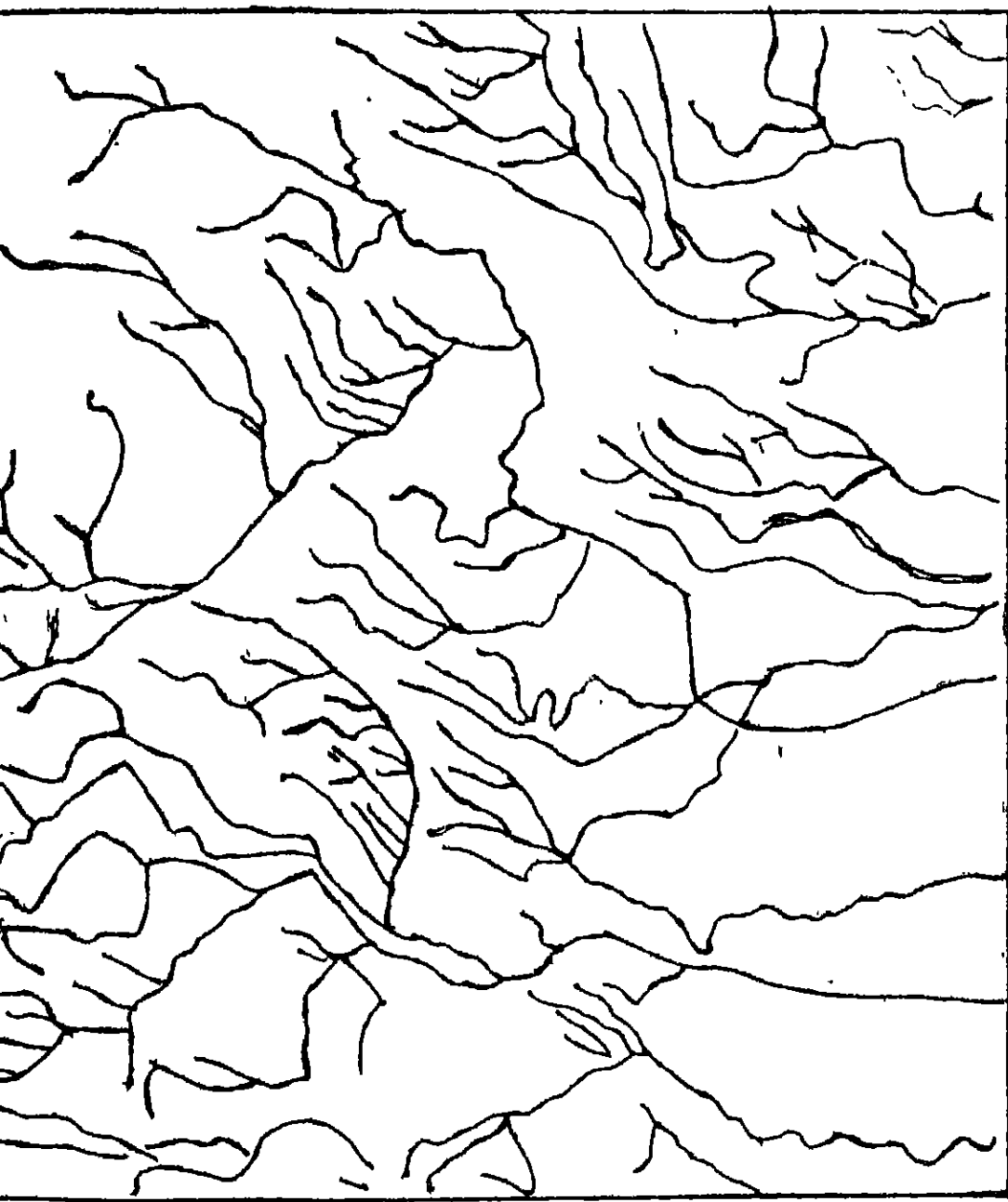


Fig 5-11 Drainage pattern of Northern India (Doon valley)

Scale = 1:1 million

I. COMPARISON OF TYPICAL VEGETATION, SOIL AND WATER REFLECTANCE CHARACTERISTICS

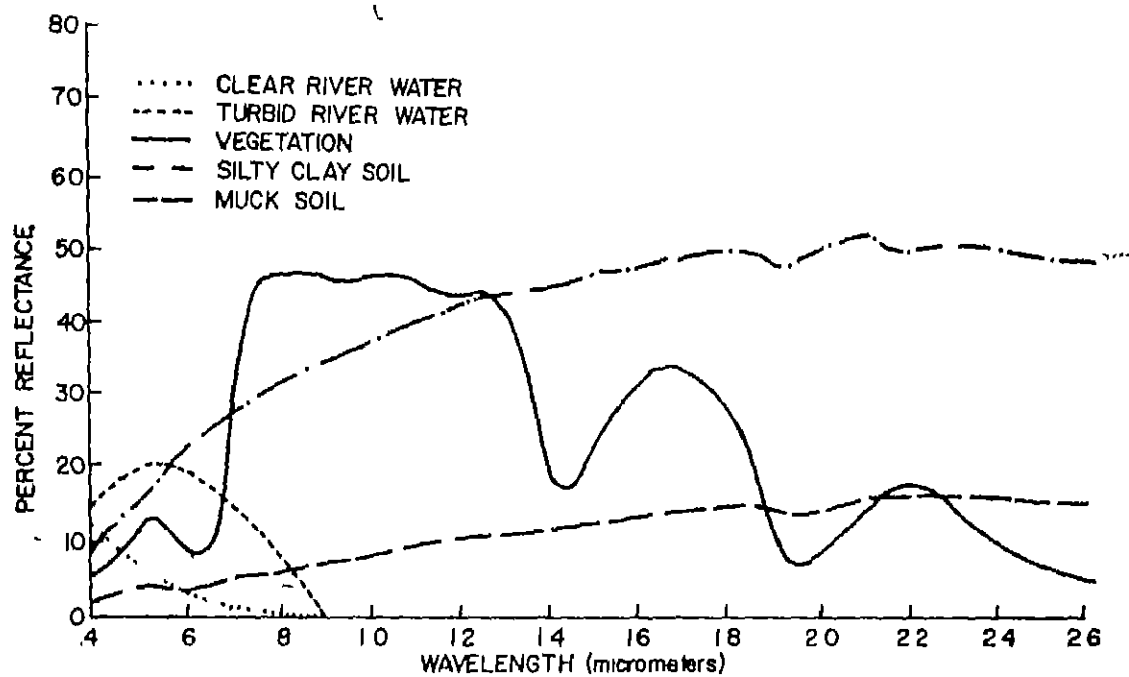


Figure 5.12 Spectral reflectance of basic cover types

Yamunotri and move towards Delhi. Vegetation and Forest are found in Himalayan region. Most of the area of plain is cultivated and properly irrigated by rivers and canals.

Due to erosion, deforestation, earthquakes, landslide and several other man made reason (Excavation of Road etc.) the pathways of springs are cut, broken, diverted, the channel of streams choked and their water polluted. The inexorable culmination of drying up of springs will be that only the flood water during the rainy season and melt water during summer and rainy season would flow in these rivers. Today 20 to 30 percentage of discharge of Himalayan river is derived from melting of snow and ice between May and September.

5.2 ALIGNMENTS OR LINEAMENTS

An alignment or lineament is defined as a mappable simple or composite linear feature of a surface, whose parts are aligned in a straight or slightly curving relationship. It can be clearly distinguished from the patterns of adjacent features and probably reflects a surface phenomenon ⁽¹⁰⁾. The surface features making up a lineament may be geomorphic (caused by relief) or tonal (caused by contrast differences). The surface features may be landform boundaries. The linear boundaries may be different types of terrain, or breaks in a uniform terrain. Straight stream valleys are typical geomorphic expression of lineaments. A tonal

lineament may be a straight boundary between areas of contrasting tone. Differences in vegetation, moisture content and soil or rock composition account for most tonal contrast. Alignments may be continuous or discontinuous. In discontinuous lineaments the separate features are aligned in a consistent direction and are relatively closed spaced. Alignments may be simple or composite. Simple lineaments are formed by a single type of feature, such as lineament are formed by a single type of feature, such as a linear stream valley or aligned topographic escarpments. Composite lineaments are defined by more than one type of feature, such as an alignment of linear tonal features, stream segments and ridges.

Alignments are well expressed on Landsat images because of the oblique illumination, suppression of distracting spatial details and the regional coverage. Linear features caused by topography may be enhanced or suppressed on Landsat images depending upon their orientation relative to the direction of solar irradiance as given by the sun azimuth. Linear features trending normal or at a high angle to the sun azimuth. Linear features trending normal or at a high angle to the sun azimuth are enhanced by shadows and highlights. Those trending parallel with azimuth are suppressed and difficult to recognise, are linear features are parallel to the MSS Scan Lines (11).

A preliminary study of lineaments on Landsat imagery was done based on recognition and identification of various linear features of terrain as picked up and marked as their images

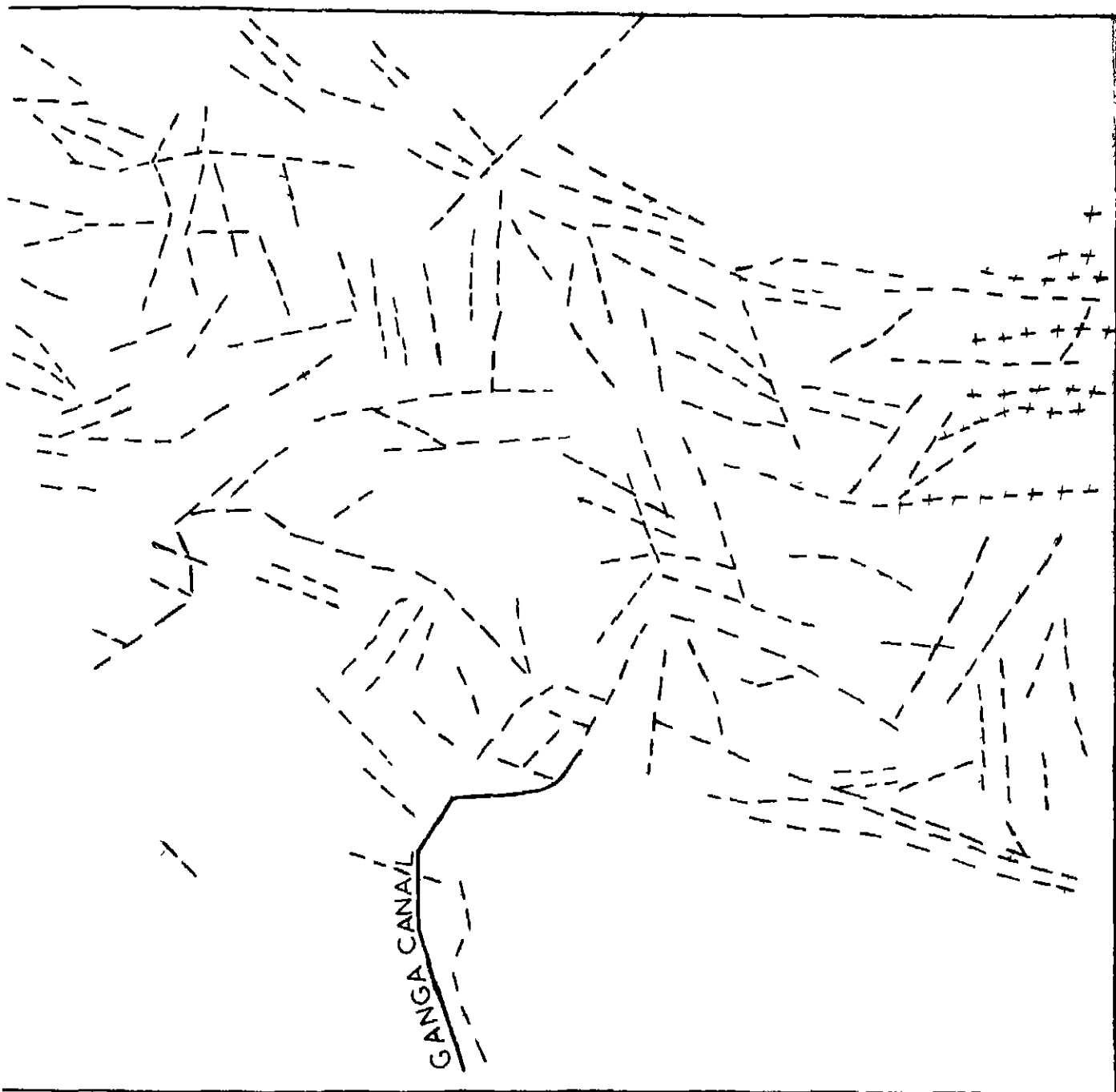


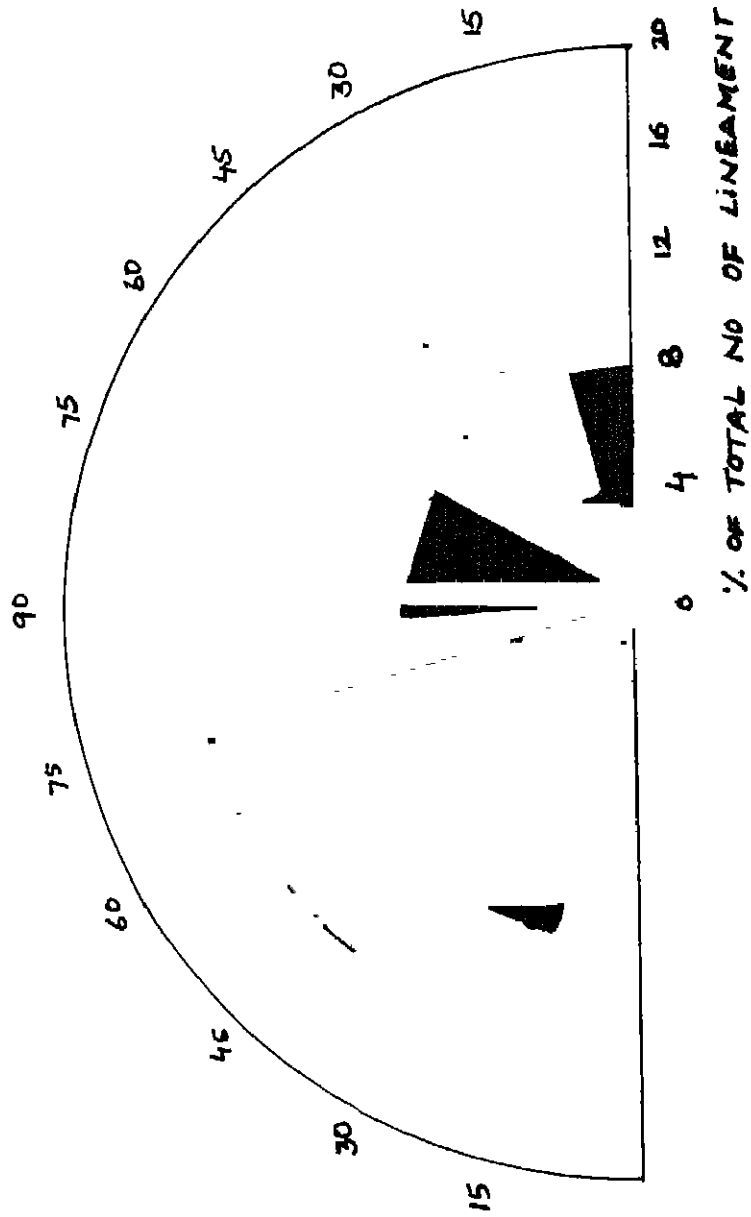
Fig. 5.21 Alignments with the dominants strike direction (NW SE & NE/SW)

Scale = 1:1million

ROSE DIAGRAM FOR LINEAMENTS

DEHRADUN REGION

FIG 5.22



(Fig..5.21). A lineament map showing minor (< 100 km), intermediate (between 100 - 300 km) and major (> 300 km) in length lineaments are prepared with a view to understand their geologic, structural & tectonic reactions. The 'Rose Diagram' (Fig..5.22) is prepared to show the general trend of lineament in the study area. It is found that most of the lineaments are in SE to NW direction (shown in Rose Diagram).

The presence of faults, folds, joints and certain physical rock characteristics may be deduced by analysing landsat imagery imagery of the alignments or lineaments. In the set up of our physiographic Landsat analysis, this static image interpretation elements lead to an understanding of the structural geology of the study area.

5.3 LAND FORM

Land form can be used as an image interpretation element. It is related to general morphology of the terrain. The morphological expression of the relief in conjunction with drainage pattern and supplemented by structural geologic deductions from alignment pattern form the backbone of a systematic physiographic Landsat analysis. Fig.5.31 shows the Landform interpretation with most delineations in the foothill tract. It shows the four major landform in the study area i.e. mountain hills, complex of high hills piedmonts and alluvial plains. Due to drainage pattern

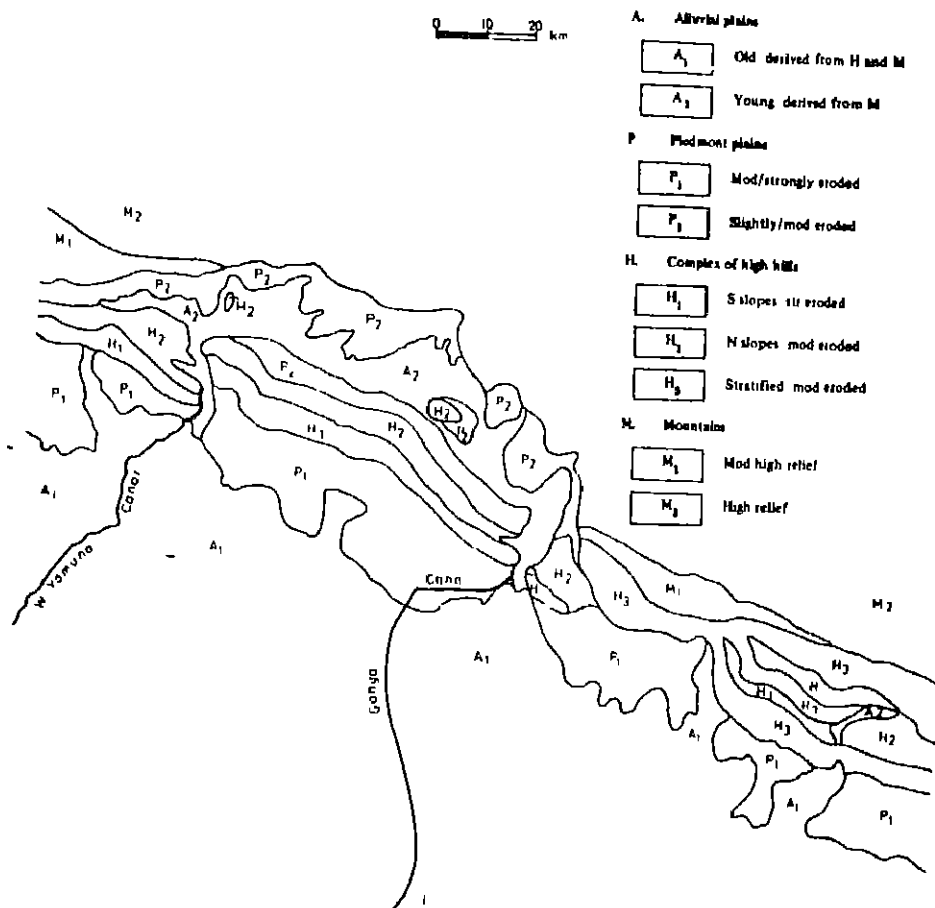


Fig 5.31 Landform (1 F) an example of landform interpretation with most delineations in the foothill tract

and physiographic expression of the relief the interpretation has become more detailed in the foothills and the piedmonts.

5.4 DRAINAGE CONDITION

'Drainage Condition' as reflecting moisture status belongs to a group of elements based 'converging evidence (Vink 1963) in modern aerial photo interpretation techniques. Open water is much more clearly indicated than subsurface water, where certain amount of deduction is allowed based upon correlating factors such as:

- i) nearness to waterlogged soils, ii) colour of the earth's surface, iii) natural vegetation/land use etc.

The element drainage condition represents all water and soil moisture close enough to surface to be detected by remote sensors. In the case of Landsat imagery, it is frequently reported that band 7 in the infra-red ($0.8 - 1.1\mu\text{m}$) is the best band. Open water canals and rivers sufficiently large to be detected come out well on Landsat imagery but for multitemporal analysis of the soil moisture regime near the surface, false colour composites (FCC's) composed of band 4, 5 and 7 or 4, 5 and 6 are preferable.

The alluvial tract shown in the Southern part of drainage condition (Fig. 5.41) analysis contain soils with waterlogging salinity and alkalinity which can be well differentiate with the Landsat imagery. Because of season dependence, this element is a typical example of a dynamic image interpretation element.

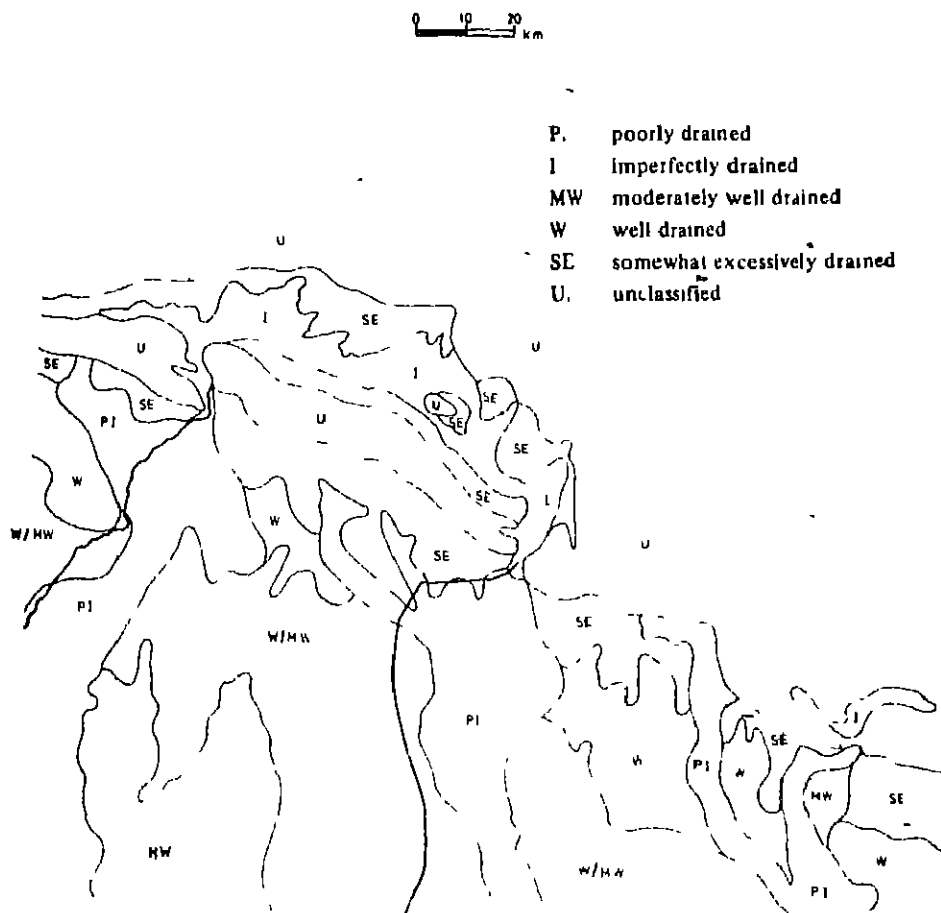


Fig 5.41 Drainage condition (DC), a dynamic image interpretation element, analysis with most delineations in the alluvial area in the South

5.5 SNOW COVER

Snow cover has no regular place in the Multitemporal Physiographic Landsat Analysis, but it has got its importance for hydrology and its influence on soil climate and vegetation, it is placed between drainage condition and vegetation because of its dynamic character and influence on both image interpretation elements.

Snow cover is a conspicuous feature recorded on Landsat imagery of high mountainous areas of world. Its extent and thickness varies according to the season and its exposure to sun irradiance.

In this study area the snow is found only at the top of Himalayas region. (Fig.5.51). The demarcation of snow line on the satellite imagery is not a difficult task but the determination of 'depth' is rather an unsatisfactory task from view point of accuracy. Figure 5.52 shows the curve of variation in reflectance with snow depth (19).

5.6 VEGETATION & LAND USE

Natural vegetation, agricultural land use and cropping pattern are strongly seasonal dependent. Because of their changing character they are grouped with dynamic interpretation elements to distinguish them from static elements such as drainage pattern and land form.

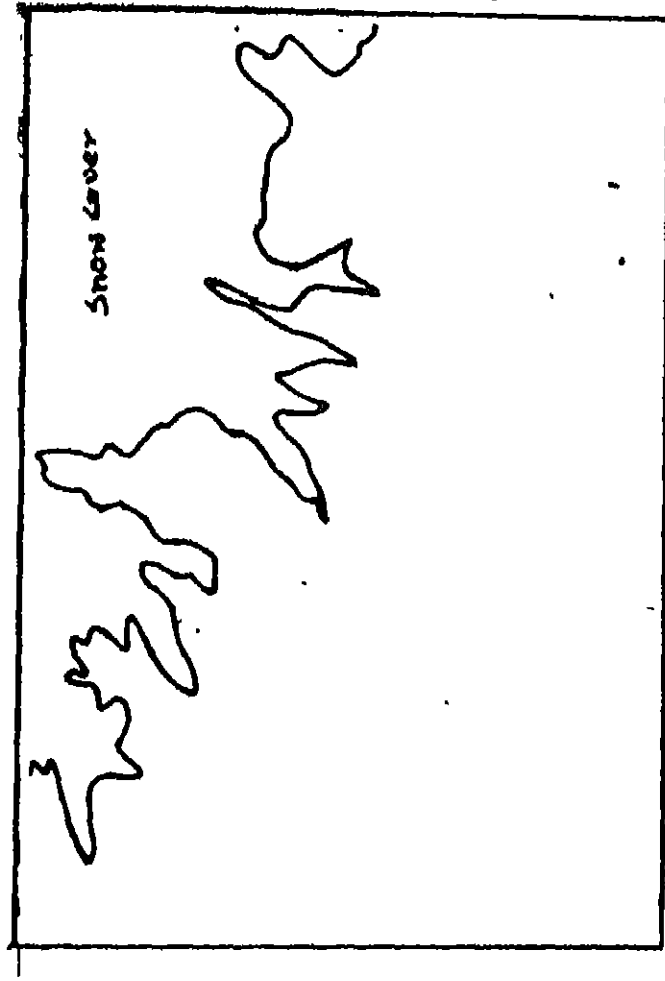


Fig. 551 Snow cover as recorded by Landsat
over a part of the Himalaya mountain
Scale 1:1million

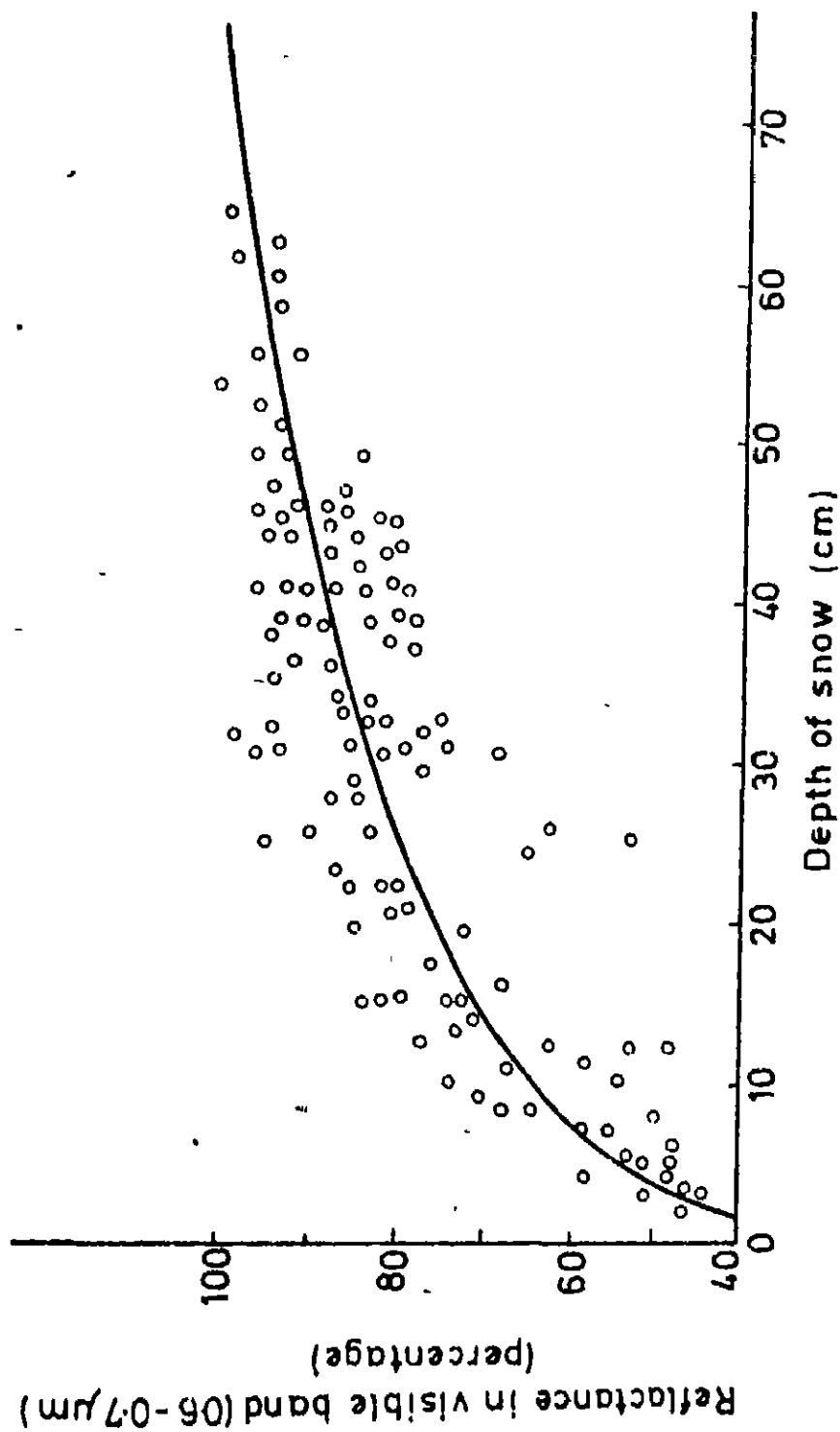


Fig 5.52 CURVE OF VARIATION IN REFLECTANCE WITH SNOW DEPTH

Fig. 5.61 (13) shows vegetation and Land use of study area. Man made structures such as towns and roads are poorly visible in the images, only the larger towns can be discussed. The best band for the interpretation of vegetation is band 5 ($0.6 - 0.7 \mu m$) because of the reflectance of vegetation is maximum at this band (Fig. 5.62). The water bodies and river were easily distinguished on band 6 & 7. For the study of forest vegetation however a combination of band 5, 6, 7 offered the best interpretation facilities.

In this study the best band filter combination for interpretation of the images was either :-

- (a) band 5 with a red filter, band 6 with green filter and band 7 with blue filter.
- (b) band 5 with a blue filter, band 6 with a green filter and band 7 with red filter.

The distinction between forest and new forest was very clear in the region of Siwalik hills (Fig. 5.61). The sal forest on the northern sides of these hills and the several small hills in the Doon Valley itself were also clearly visible. In the Himalayan foothills the difference between forest type was not great enough to allow of delineation. This is due to the fact that vegetation cover on the hills consist of patches of forest land, patches of scrub, the patches of grass land and the resolution of the Landsat imagery was not enough to offer a clear distinction between these these type of vegetation.

The result was mottled pictures in which it was only possible to delineate an 'average' type. For the same reason it was only impossible to distinguish terraced agriculture in the hills.

The dry deciduous forest on the ridge was also visible. The delineation of this type differed significantly from the map however the reason for this might be that there is a transition zone between forest consisting of *Shorea robusta* with only a small admixture of other species on the northern side of Siwalik and the drier and poorer mixed deciduous forest on their southern side. The latter type has very few sal trees. In the zone between the two types, there is a marked admixture of *Shorea robusta* trees in the forest canopy. The transition zones seem to be well developed in the Western and Central Siwaliks but not in the east and it was therefore not distinguishable in the imagery.

The vegetation at the southern edge of Siwaliks where the Ganga-Yamuna plain begins consists of mixed deciduous forest and plantations. In some cases where the plantations are large (150 to 200 hectares), and differed significantly from the surrounding forest, they could be distinguished. The resolution of imagery however does not allow the smaller areas to be delineated properly.

The most of the built up and cultivated areas are in plain (of study area) Rishikesh, Haridwar are situated at the bank of river Ganga while Roorkee, Muzaffarnagar are situated at the bank of Ganga Canal (Fig. 5.63). Saharanpur is about 80 km far

Fig 5.61

FOREST AND LAND USE MAP

scale 1:250,000

14	Northern dry mixed deciduous forest on flat areas
15	Northern dry mixed deciduous forest on hill as areal (poor)
16	Tropical hill valley swamp forest
17	Tropical hill valley swamp forest (poor)
18	Northern dry mixed deciduous forest on Swetik hills
19	Northern dry mixed deciduous forest on Swetik hills (poor)
20	Himalayan subtropical forest
21	Scrub forest (subtropical scrub forest) (open)
22	Sai (Shorea robusta) forest
23	Plantation
24	Khar vaoon (Acacia saligna)
25	Dalbergia sissoo (Acacia catechu)
26	Dalbergia sissoo forest (open)
27	Himalayan chir pine (Pinus roxburghii) forest
28	Ban oak (Quercus rostrata) forest
29	Moist Deciduous (Cedrus deodars) forest
30	Grassy areas
31	Cultivation
32	Integrated cultivation
33	Terraced cultivation
34	Habitat
35	Tea gardens and orchards
36	Main road
37	Main stream
38	Tributary
39	Town



III. COMPARISON OF TYPICAL VEGETATION, SOIL AND WATER REFLECTANCE CHARACTERISTICS

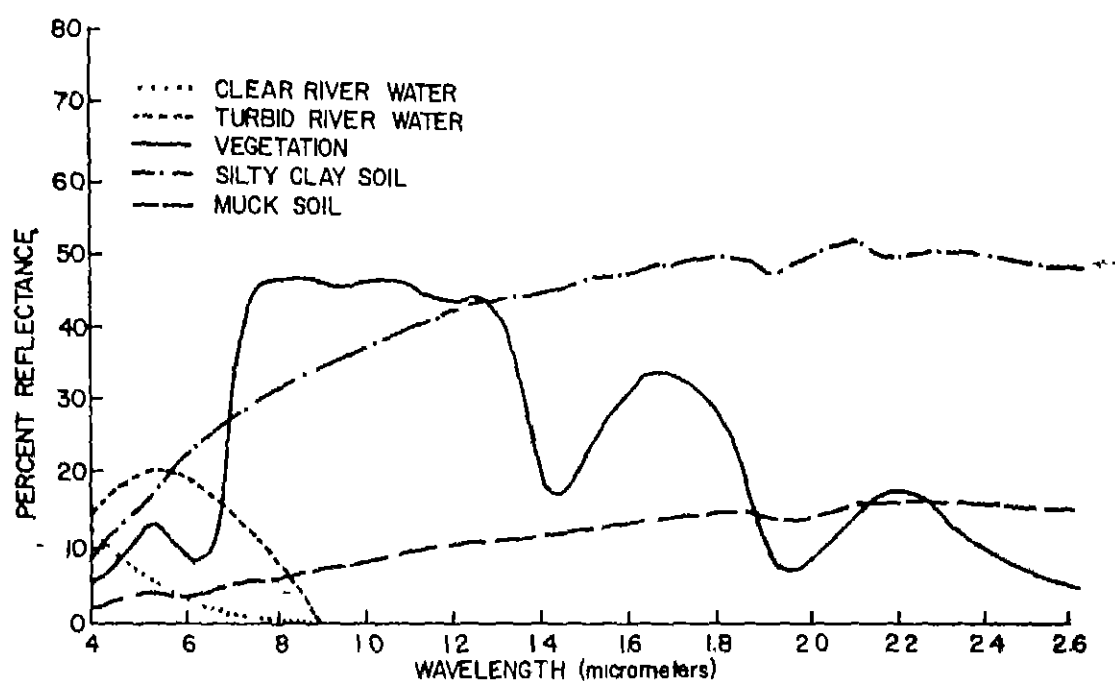


Figure 5.62 Spectral reflectance of basic cover types

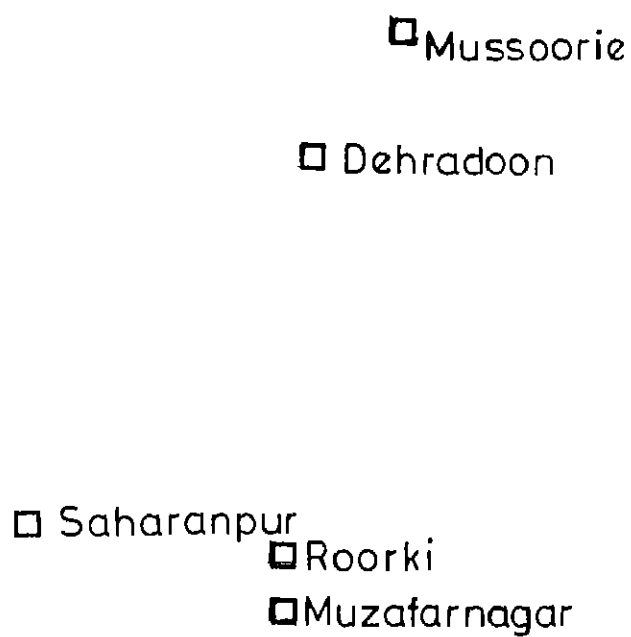


Fig. 5 63 Built up area Doon Valley

Scale 1:1million

from Roorkee in west direction. The all the above cities are thickly populated. In the Valley of Siwalik Hills the city Dehradun, the famous hilly station Mussorie is situated. The city & town which is thickly populated can be identified easily by the visual interpretation of Landsat imagery. The places like Uttarakashi, Gangotri, Yamunotri which is situated at the Himalayan mountain can not be identified easily but can be intercepted with the help of map. The built up area covers 5 to 7 % of total study area.

5.7 PHYSIOGRAPHIC ANALYSIS

The concept of land is the centre of our physiographic approach to satellite image interpretations where as aerial photo-interpretation is generally concerned with mono temporal stereoscopic photography. Landsat imagery though at present low in spatial resolution is very well turned to the dynamic aspects of reconnaissance land and land use surveys because of its repetitive coverage of the earth's surface.

It is worthwhile to evaluate Landsat imagery from the point of view of the Land attributes in the widely used definition of 'land' by Christian and Stewart (1968) "A tract of land is defined geographically as a specific area of the earth's surface, its characteristics embrace all reasonable stable, or predictable cyclic, attributes of the biosphere vertically above and below this area including these of the atmosphere, the soil and the

underlying geology the topography, the hydrology, the plant and animal populations and the result of past and present human activity to the extent that these attributes exert a significant influence on present and future uses of land by man".

The backbone of the physiographic Landsat image analysis is determined by Landform, which is based upon the morphological expression of relief and supported by drainage pattern, parameters for geological structure's hydrology, lithology, (soil parent material) and topography.

Fig. 5.7' (6) shows the multitemporal physiographic analysis with a part of the Himalayan Mountains, the Siwalik foothills and the alluvial Indo-gangetic plain near Dehradun (Northern India study area).

It shows that in plain area the most of soil is alluvial they are in of smaller size and transported by the river (Ganga, Yamuna) from mountains. However the old alluvial soil are well drained but the young alluvial plain are poorly drained. The marshy land is also found in plain area.

In the south of complex high hill piedmont plains are found which are somewhat excessively drained, moderately to strongly eroded, and some places sparse and mod dense vegetation are also there. In North of complex high hills and south of mountain area excessively drained, slightly to moderate eroded plains, deciduous forest and fine textured vegetations are available.

On the complex of high hills (Siwaliks) in southern side parallel slope controlled drainage patterns strongly eroded deciduous forest, dense fine textured vegetation, mod dense, mod degraded coarse textured vegetation are available. However in Northern side parallel slope controlled drainage pattern, moderately eroded, dry deciduous forest, dense fine textured, vegetation are found, but on the Himalayan Mountain moderately high strongly structurally controlled drainage pattern, evergreen forest, mod dense, mod degraded, coarse textured vegetation are available.

The various type of plains and vegetation which are available in the study area can be summarised in table 5.7.

TABLE 5.7

Alluvial Plains

- A1 Old Alluvial Plain
 - A11 Old Plain, well drained
 - A12 Levees, well drained
 - A13 Old Plain, moderately well drained
 - A14 Drainage ways and halomorphic depressions, imperfectly drained, grazing land (A₁₄₁) and bare (A₁₄₂)
- A2 Young Alluvial Plain, sub-recent
 - A21 Imperfectly to poorly drained, cropland and rainfed (A211) and irrigated (A212), cropland and forest plantations (A213)
 - A22 Marshy, very poorly drained
- A3 Floodplain, recent, deposits, imperfectly to poorly drained
- A4 River courses

Piedmont Plains

- P1 South of the complex of high hills, somewhat excessively drained, moderately to strongly eroded
 - P11 Forest plantation and cropland, mod dense vegetation
 - P12 Rainfed cropland with sparse (P121) and mod dense (P122) vegetation
- P2 North of the complex of high hills and south of the

mountainous area, somewhat excessively drained, slightly to moderately eroded

P21 Dry deciduous forest, dense, fine textured* vegetation

P22 Forest plantations and cropland, mod dense vegetation

Complex of high hills (Siwaliks)

H1 Southern slopes, with parallel slope controlled drainage pattern strongly eroded dry deciduous forest.

H11 Dense, fine textured vegetation

H12 Mod dense, mod degraded, coarse textured vegetation

H2 Northern slopes, with parallel slope controlled drainage pattern, moderately eroded, dry deciduous forest

H21 Dense, fine textured vegetation

H22 Mod dense, mod degraded, medium textured vegetation

H3 Stratified, moderately eroded,

H31 Fine textured

H32 Coarse textured

Mountains (Himalayas)

M1 Moderately high, strongly structurally controlled drainage (trellis) pattern, evergreen forest

M11 Mod dense, mod degraded, coarse textured vegetation

M12 Sparse, degraded, coarse textured vegetation

M2 Highly elevated, strongly structurally controlled drainage (trellis) pattern, evergreen forest.

- M21 Dense, non-degraded, coarse textured vegetation
- M22 Mod dense, mod degraded, coarse textured vegetation
- M23 Sparse, degraded, coarse textured vegetation

* Image textures refer to relief variations



Fig 5.71 Multitemporal physiographic analysis (P1) with a part of the Himalayan mountains (M), the Siwalik foothills (H) and the Alluvial Indo Gangetic plain (A), near Dehra Dun U.P., Northern India interpretation based upon the following scenes Dec 72, Feb 73, May 74 and July 74

CHAPTER - VI

REGIONAL GEOLOGY

Table 6.1 summarises geological succession of the area. Accordingly Siwalik system is interesting for more than one reasons. It is overlain by older pre-tertiary rocks of Chandpur. Hence the contact between them definitely shows evidence of thrusting, which is called Krol thrust. Other features like slickensides, silicification of fractured rocks also confirm the presence of a thrust plane. (Fig. 6.1) (20). South ward lie the Lesser Himalayas with comparatively mild topography, rising to the max elevation of 2600 m and characterized by gentler slopes but deeply dissected valleys. The junction is defered by a gently inclined split plane of movement of rock masses called the main central thrust. This plane had served in the geological recent past as the plane along which the lesser Himalayan domain-forming the northern front of the Indian subcontinent slid or slipped under the great Himalayan pile.

This under sliding of the Lesser Himalayas Crustal plate led to the uplift of great Himalayans to an immense elevation and resulted in the whole sale splitting shearing, shattering and crushing of Lesser Himalayan Rock. On the southern side yet another boundary fault - ~~the~~ main boundary thrust-separates the Lesser Himalayas from the forested Siwalik, forming the frentier

rampart. The Indian Crust is presently slipping under the Himalayan Crust at shallow angles of $15^{\circ} \pm 5^{\circ}$ along the main Boundary Thrust. This is evident from the occurrence of earthquakes of high magnitude (eight or more on the ^{Richter} Richard Scale), though less frequently.

The Chandpur phyllites seem to be prone to land slides. Chandpur which are then bedded (1 to 3 mm) show the alternation of quartzite and phyllite giving a fine banded appearance. The chloritic rocks and slates exhibit polygonal jointing. At places, Nagthats are seen to overlie, the folded and disturbed Chandpur phyllites which vary in colour as black, purple, brown and so on.

Krol series in which caves have formed comprises of massive limestone which show five subdivisions with an aggregate thickness of 600 meter. Upper Krols are for the most part dolomitic, the limestone of middle division are crystalline and the lower portion comprises of impure limestone. This limestone sequence is believed to be of shallow marine origin (Valdiya 1975, Pandey, 1976). In addition to the above minerals the 'rock phosphate' is also found at MALDEVOTA, a place very close to Rajpur.

Although all type of minerals can not be interpreted by satellite imagery, the only surface thing can be interpreted by the satellite imagery. But with the help of Geological map of the study area the minerals can be interpreted with more confidence.

TABLE - 6.1

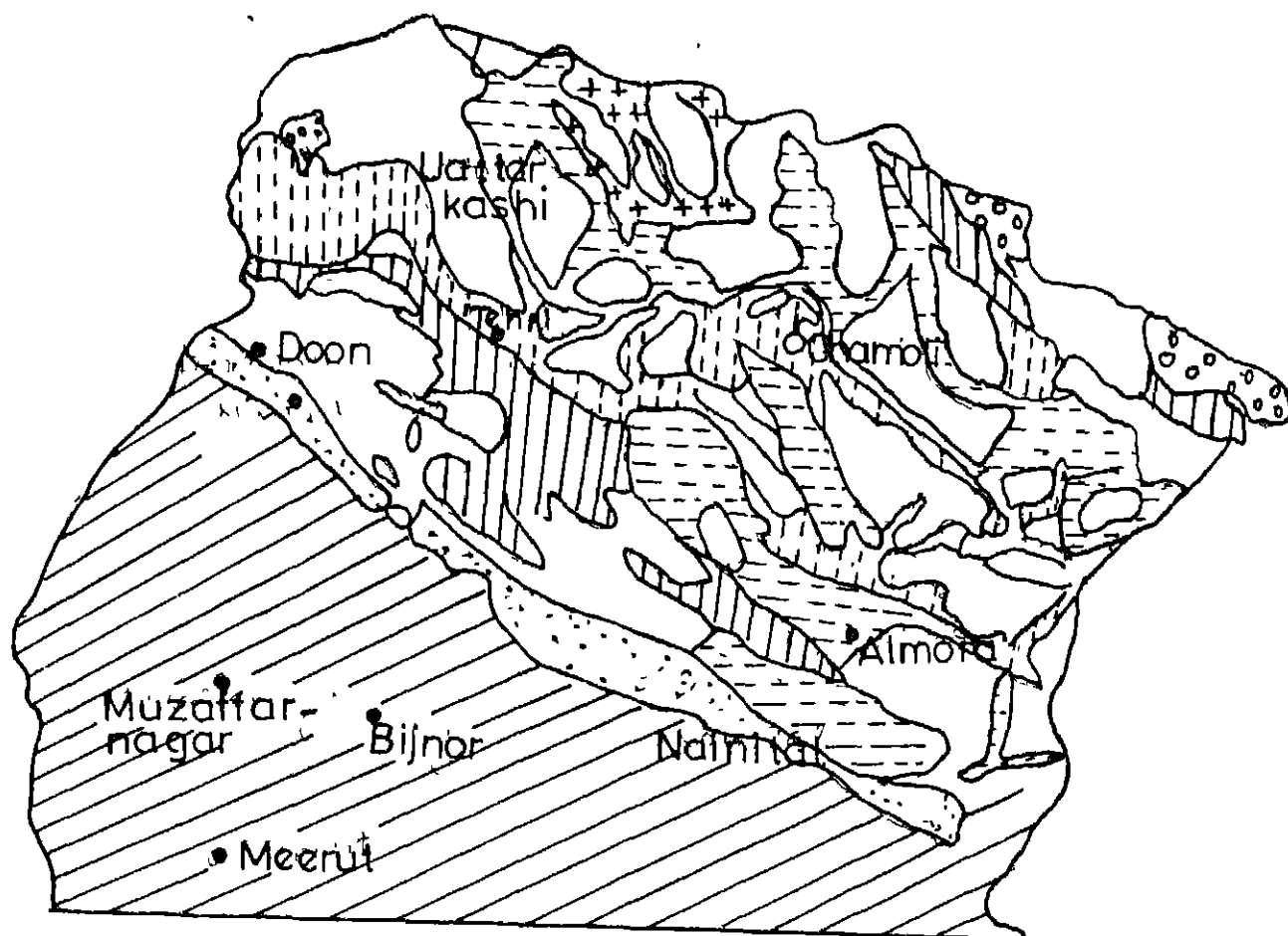
GEOLOGICAL SUCCESSION IN DEHRADUN-MUSSOORIE AREA

<u>Name</u>	<u>Rock Type</u>	<u>Age</u>
Upper Siwaliks	Coarse Sandstones, Conglomerates	Pliocene (11 M.Y.)
Lr. and Mid. Siwaliks	Sandstone, Shale	U. Miocene (25 M.Y.)
Upper Tal	Quartzites	Jurassic (180 M.Y.)
Lower Tal	Shales, Slates (Phosphorite)	
Upper Krol	Limestone (Dolomite dykes)	
Mid Krol	Red Shales	Triassic (225 M.Y.)
Lower Krol	Limestone	Permian (270 M.Y.)
Infra Krol	Slates	
Blaini	Boulder Bed, Slates	U. Carboniferous (300 M.Y.)
Nagthat	Quartzites	Jaunsar Series Devonian (400 M.Y.)
Chandpur	Slates and Phyllites	
Mandhali	Limestone	
Dooban	Limestone	Cambrian (600 M.Y.)
Simla	Slates	Pre-Cambrian

(Modified after Krishnan, 1968)

Geological map of Doon Valley

Scale 1:2250,000



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	ALLUVIUM DUN GRAVEL
	SIWALIK SYSTEM
	HAIMANT & CHANDRAPUR GROUP
	CENTRAL HIMALAYA GNEISSES WITH GRANITE SCHISTS QUARTIZTES
	GRANITES OF HIMALAYA
	DECCAN TRAP
	TRIASSIC GROUP

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UPPER SIWALIKS

LOWER SIWALIKS

FAULT THRUST

POOL LIMESTONE

MUSKOTI QUARTZITE

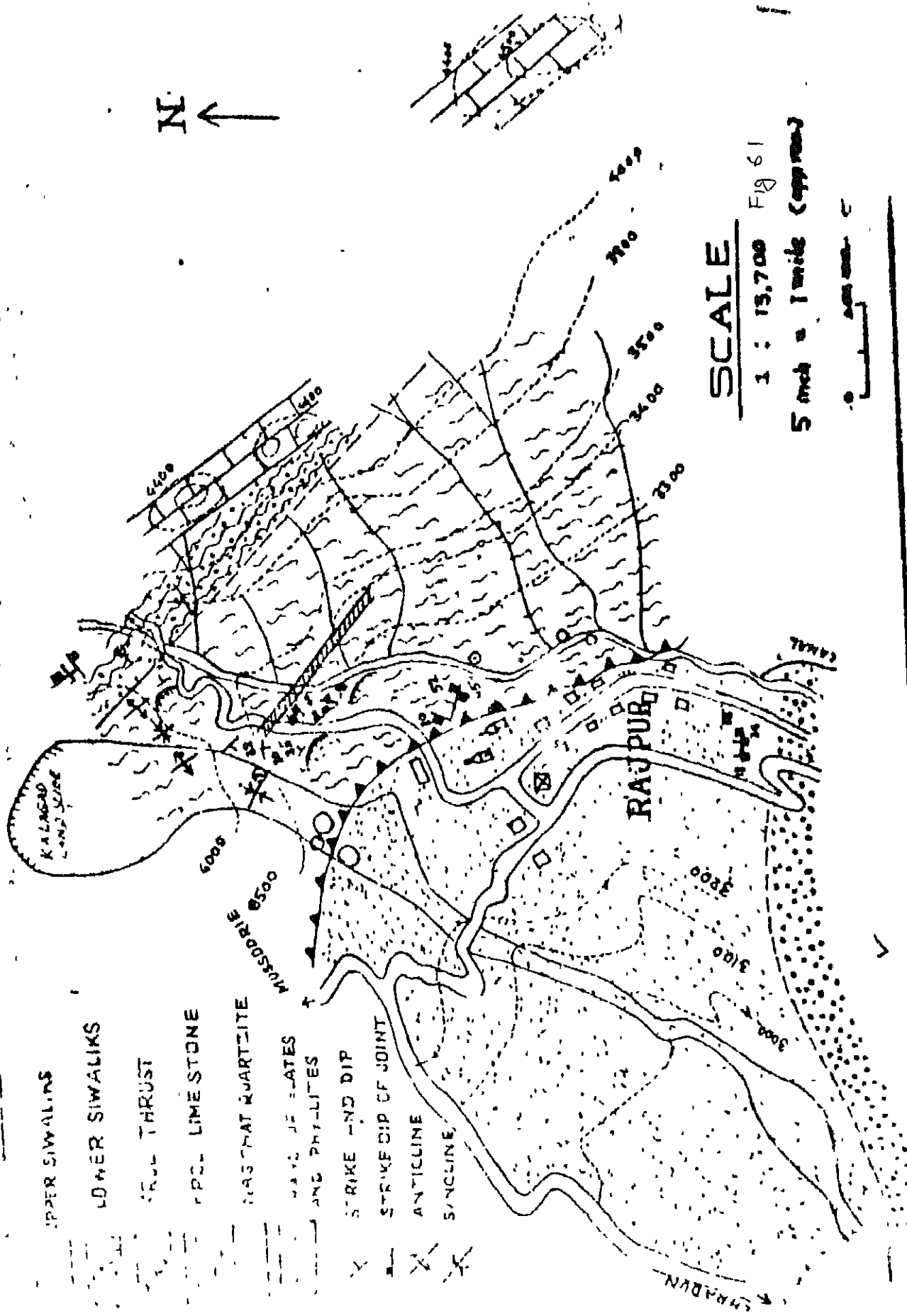
MUSKOTI SLATES
AND PHYLITES

STRIKE AND DIP

STRIKE DIP OF JOINT

ANTICLINE

SYNCLINE



SCALE

1 : 13,700 Fig 61

5 inch = 1 mile (approximate)

0 1 2 3 4 5

CHAPTER - VII

DISCUSSION

7.1 REPEATED SHAKING BY EARTHQUAKES

Coupled with the inherent weakness of the rock succession, the main central thrust belt repeatedly shaken by earthquakes. The earthquakes have further ravaged the terrain, loosened the rock masses, precipitated huge land-slides and rendered the terrain alarmingly unstable in certain areas. In the outer belt earthquakes related to main boundary thrust are less frequent but greater in magnitude and severity.

The occurrence of earthquakes implies movements largely in the direction of inclination of thrust plane (dip-slip) and partly in the direction of their trend (strike-slip) some of the events are related to horizontal movements in the direction of trends of the roughly north-south oriented faults that have torn the terrain into blocks. These phenomenon are in consonance with the the notion of Lesser Himalayan plate slipping or sliding under the stupendous Great Himalayan slab. One fact is quite obvious even if an area has not been visited upon by earthquakes, the faults that run in the north-south, NNE-SSW, NNW-SSE directions, that is, traverse to mountain trend have caused extreme damage to the stability of rocks by shearing, shattering and pushing them out of place. Many of these tear faults are quite active, serving as they do as the planes of movement resulting from the northwards

drift of the Indian subcontinent. The areas that have been cut by these faults are particularly vulnerable to mass movements like landsliding, slumping and rockfalls. They are therefore, most sensitive to and unsuitable for all engineering activities.

7.2 ACCELERATED PACE OF EROSION

The geodynamically sensitive belts and areas are thus succumbing to deep and extensive erosion. Every ten years about 1 cm thick soil over the whole Himalayan region is washed away by streams. In other words, every 100 sq km area of catchment of the major rivers, in which dams have been constructed, is contributing sediments that can build a 1 m high pile over a plot of 16 $\frac{1}{2}$ hectares. In the boundary thrust zones, the rate of erosion is five to seven times more than it was in the recent past.

7.3 EROSION & DEFORESTATION

Removal of the protective cover of vegetation from large parts of the Lesser Himalayan terrain is undeniably the principal cause of accelerated rate of erosion. Deforestation resulting from overgrazing by an explosively growing population of cattle (at the rate of 0.18 percent per year) and the reckless exploitation of forests for a variety of purposes have reduced the tree cover to about one third of the surface area of Lesser Himalayan domains. So that today two thirds of area is exposed to the quickened pace of erosion. A study by J.S. Singh & A.K. Saxena

of Kumaun University (18) shows that in central sector the pressure of grazing is $2\frac{1}{2}$ to $4\frac{1}{2}$ times the supporting capacity of the forest and pastures, a situation comparable with that in Iraq (four times) and Syria (three times).

The per unit cattle has 0.3 to 0.6 ha of grazing land. As a result the forest have been defoliated, the grasslands trampled, their nutritious vegetation smothered and the mountain-sides extensively furrowed.

The age old Cruel practice of settling fire to forest be ensure quicker growth of fodder grass has not only damage the forest, but also weakened, the soil consederably. Studies carried out in an experimental forest in Siwalik demonstrate that the peak flow of rainwater that runs down the slope on the surface increased by 69 percent as a result of burning forest, by 34 percent following clear felling, and by 32 percent due to overgrazing.

More runoff water means higher incidence of flood and greater denudation. The roots of trees and shrubs, thrust deep into the soils or rocks, provide additional strength against destabilization, dislocation and consequent removal. The distruction of vegetation naturally weakens the anchorage the roots provide, making the soils and rocks vulnerable to landslides and related to mass movement.

7.4 ROAD CONSTRUCTION & INSTABILITY OF HILL SIDES

The biggest factor responsible for severe damage to the stability of the hill sides and promotion of erosion is the making of unimaginatively planned and cruelly executed roads. The construction of 1 km long roads generates, on an average 40,000 to 80,000 Cu m of debris. There are over 45,000 km of Khchhapakka (dirt and metalled) roads in the Himalayan region. The debris generated must have been of the order of 2650 million Cu m. That is not all Landslides and rockfalls on every kilometer stretch of road built by the Border Roads Organization produces on average 550 Cu m of debris per year. These debris causes enormous damage to the downslope vegetation, agricultural fields and the surface and underground water system. The Road Construction activities not only increase the incidence of landslides (several times) but also stimulate erosion in the channels of rivers and stream.

7.5 IMPACT ON SPRINGS AND WATER BUDGET OF RIVERS

The impact of deforestation and erosion in the Himalayan region has been very profound and far reaching on the geohydrological systems of springs and seepages that feed streams and rivers. The loss of vegetal cover has reduced the capacity of sloping grounds to absorb and infiltrate rain waters and feed the springs, leading to their drying up or going seasonal. A spot survey in the Himalayan region revealed that 40 to 45 percent of springs

have either gone dry or become seasonal. This is discernible everywhere in the areas where forest have been removed from water sheds and where road construction has severely damaged the water system both surface or underground.

Excavation for roads causes drastic changes in the geohydrological system of the water the pathways of spring are cut, broken or diverted, the seepages and springs are smothered with the masses of debris, the channels of stream choked and their water polluted. In the absence of springs, there would be no water in the streams and the rivers they feed. And if the present state of affairs is allowed to continue, the discharge in Himalayan rivers will dwindle considerably. The inexorable culmination of the drying up of springs will be that only the flood waters during the rainy season and melt water during summer and rainy season would flow in these rivers. Today 20 to 30 percent of the discharge of the Himalayan river is derived from melting of snows and ice between May and September.

Further more, the excessively runoff flowing down the valleys of channels due to reduced capacity (due to the accumulation of debris and sediments) have caused floods in fertile fields in the plains with regular periodicity and growing magnitude of damages. The 15 million hectares of land of the Indo-Gangetic plains where 40 percent of the Indian population lives, suffer from 60 percent of flood damages experienced by the country. In spite of flood control measures taken, the dimension of flood hazards is increasing phenomenally.

7.6 SIGNS OF DESERTIFICATION

With large parts of the Lesser Himalayas affected by erosion, the groundwater threatened with deprivation and the fast multiplying numbers of humans and cattles devouring vegetal resources and encroaching upon geologically sensitive and ecologically vulnerable areas. Certain **irreversible** changes have taken place that endanger the very life support system.

As already stated, almost two thirds of the Lesser Himalayan areas has been deprived of forest cover, and where there are forest, the tree canopy is just not adequate to protect the soil. The vegetation has a profound influence on the microclimate within the soil. In the absence of the vegetal cover it gets rapidly heated up and is uninhibitedly beaten by the rains and wind. A study by Fraz Kollmannsperger shows that the evaporation of the moisture in the soil of Himalayan region is as high as 190 percent, inevitably leading to progressively drying up of ground surfaces. In the absence of humus (organic matter generated by the vegetation) the soil became hard and impervious to the infiltration of water and air, thus preventing the growth of plants and eventually culminating in the breakdown of the nutrient cycle.

An analysis by S.L. Shah (18) shows that from total growing stock of 66 million Cu m of forest in Himalayan region and gross annual increment of 0.78 million Cu m. The out turn is 4.54 million Cu m so that the net yearly depletion is 3.76

million Cu m. The exponential rate of depletion is 5.8 percent of annum, implying that the forest capital is being eaten away rapidly. The cattle population is growing at an exponential rate of 0.18 percent per annum and the net rate of depletion of grass stock is 5 percent per annum. At the present rates of exploitation the carrying capacity of forest would be over reached by 2031 AD and that of pastures by 2041 AD. In other words there would be no forest left by 2031 AD and no grasslands by 2041 AD. The Himalayas would then be a desert domain.

CHAPTER - VIII

CONCLUSION

The visual interpretation of natural resources by the Landsat imagery is much effective and efficient for large areas. Same time it is economical also. One Landsat imagery covers a lot of area (185 km x 185 km) and one can easily get idea about the drainage pattern, lineaments, drainage condition, geology of the area is very less time as compared if field survey is done, compared with small scale aerial photography Landsat imagery has definite advantage in the domain of multispectral and multitemporal scanning of earth's surface. Although at present Landsat has a low spatial resolution and its imagery still offers only limited possibilities.

Image interpretations differs from direct observation in aerial scope, perspective and temporal relationship. It is similar to direct observation in one important respect, the amount and reliability of the information obtained depends upon training and aptitude of observer and on nature of scene observed.

The Landsat images used for the study of Dehradun area (Northern India) have path No. 157 and row No. 39. The results obtain from the imager interpretation as lay down in objective can concluded as following.

- (1) There are two major rivers in the study area. Ganga & Yamuna Small springs and their several tributaries are found on Himalayan region. Most of the springs are seasonal. Snow is found on the top of Himalayan mountain which is main source of discharge for the rivers and springs.
- (11) There are two major canal, one is taken off from Ganga and other is from Yamuna, which are the main source of irrigation of Indo-Gangetic plain.
- (111) The general trend of the lineament or alignment in the study area is in SE to NW direction.
- (1v) The four major land form is available in the study area i.e. mountain hills, complex of high hill, piedmonts and alluvial plains.
- (v) The alluvial tract on the southern part of drainage condition contains soils with water logging salinity and alkality which can be easily differentiate with the Landsat imagery.
- (vi) The top of Himalaya Snow is found. The demarcation of snow line on satellite imagery can easily done but the determination of depth is difficult because its thickness varies according to season and sun irradiance.
- (vii) Most of the built up & cultivated area lies in Indo-Gangetic plain. Because this plain has got fertile land and properly irrigated by river and canal. However the built up area cover 5 to 7 % of total study area.

- (viii) The Indo-Gangetic plain is thickly populated as compared with the hilly region. The 60 to 70 % population of study area lives in the Indo-Gangetic plain, (Doon Valley).
- (ix) On the Southward side of lesser Himalayas the main central thrust is found. On the Southern side yet another boundary fault - the main boundary thrust is found. The Krol thrust is also at Chandrapur.
- (x) The most of the area of Himalayan region have lime stone, although quartzite and phyllite are also seen to some places.
- (xi) The main reason for the faults folds, landslide, is earthquakes, erosion of soils, deforestation, grazing by cattle, Road Construction etc.
- (xii) The erosion of soil is so fast in the Himalayan region that every year $\frac{1}{10}$ cm thick soil over whole Himalaya region is wasted away by streams.
- (xiii) Removal of vegetation of large part of the Lesser Himalaya is the principal cause of accelerated rate of erosion.
- (xiv) The biggest factor responsible for the severe damage to the stability of the hill side and promotion of erosion is the making of unimaginatively planned and cruelly executed roads at Hill side.
- (xv) The peak flow of rain water that runs down the slope on the surface increased, by 69 percent as result of burning

forest, by 34 percent following clear felling and 32 percent due to over grazing.

- (xvi) Due to deforestation and erosion in the Himalayan region the 40 to 45 percent of spring have either gone dry or seasonal.

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